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THESIS

DESIGN AND IMPLEMENTATION OF A WORLD WIDE WEB AMATEUR SATELLITE GROUND STATION GATEWAY

by

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September 1995

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The approach taken to solve this problem was to create two conversion programs. The first program converts the PFH format to HTML for directory listings of messages and the second program decodes the telemetry downloaded from the satellites to a text file, both of which are made available to the World Wide Web server.

The result is a gateway between the Amateur Satellite Service and the World Wide Web so that users can access the message database and telemetry of each satellite using a World Wide Web browser program. The gateway has averaged 350 accesses per day during five months of operation from 3057 hosts in 41 countries. Several email messages have also been received commenting on the gateway's uniqueness, utility, and originality.

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DESIGN AND IMPLEMENTATION OF A WORLD WIDE WEB AMATEUR SATELLITE GROUND STATION GATEWAY

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Submitted in partial fulfillment
of the requirements for the degree of

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ABSTRACT

The problem addressed by this thesis project is to connect two global networks, the Amateur Satellite Service with the World Wide Web. The ground station computer formats its data in the PACSAT File Header (PFH) format and the World Wide Web requires Hypertext Markup Language (HTML) format.

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I. INTRODUCTION

A. BACKGROUND

The *World Wide Web Amateur Satellite Ground Station* Gateway (Figure 1) (http://gndstn.sp.nps.navy.mil) permits users to access the message database and telemetry of three low-Earth orbiting Amateur digital communications satellites via the Internet's World Wide Web (WWW). The World Wide Web was chosen because of its ease of use graphical user interface and popularity with the users of the Internet. The Amateur Satellite Service was chosen to tap into a world-wide pool of enthusiastic experimenters. The goal of this thesis is to implement a gateway between these two global networks, a feat that has never been done before.

The WWW is quite possibly the fastest growing facet of the Internet today. It is characterized by its intuitive and easy to use graphical user interface client program, sometimes called a browser or navigator, which is available for a variety of computing platforms. The World Wide Web was conceived at the European Particle Physics Laboratory, CERN, in Geneva, Switzerland. The Web's designers sought to combine information from related projects through hypertext [1]. Eventually, the University of Illinois' National Center for Supercomputer Applications (NCSA) took the idea one step further and created the popular NCSA Mosaic browser program [2]. Since the introduction of the World Wide Web in 1990, its popularity has surpassed everyone's expectations. Prospective users can access the World Wide Web from work, school, and through major information providers such as CompuServe® or America Online® as well as many local Internet Access Providers.

The Amateur Radio Service is an international avocation of radio enthusiasts around the world. Within the Amateur Radio Service is the Amateur Satellite Service, both used for the intercommunication between "Ham Radio" operators. There are two types of Amateur Satellites in orbit: analog "bent pipe" and digital store-and-forward communications. The analog transponders operate as a repeater in the sky, transmitting on the down-link in real-time the up-link transmission. Thus Amateurs can communicate via voice to one another via the

satellite. Digital communications satellites operate as a "bulletin board" in the sky. Electronic mail can be uploaded to the satellite, stored, and transmitted later when the satellite orbits over the intended receiver. Thus digital satellites communicate in non-real-time.

B. GATEWAY IMPLEMENTATION

The *World Wide Web Amateur Satellite Ground Station* Gateway is located at the Naval Postgraduate School in Monterey, CA. It is part of the Satellite Development Program in the Space Systems Academic Group. The gateway is an outgrowth of the Amateur Satellite ground station that is provided for students to learn about the operation of low-Earth orbit digital communications satellites.

The gateway was implemented by integrating a World Wide Web server program with an Amateur Satellite ground station. The ground station was constructed with commercial off the shelf (COTS) Amateur Radio equipment. A computer controls the ground station operation, tracking and exchange of messages. On the ground station computer the World Wide Web server program was installed. To complete the integration of the ground station with the server program, two custom programs were written to format the ground station files into hypertext markup language (HTML) files for the World Wide Web server.

The gateway was placed into operation April 11, 1995. It has been in operation for over five months. In that time period over 350 accesses per day average have been logged. Forty-one countries have accessed the gateway from 3057 hosts computers. The operation of the gateway has allowed many people around the world the ability to investigate possibilities for an Internet to satellite gateway that were previously unexplored. It has also invoked a dialog into many possible enhancements and uses for the gateway in real world situations.

C. OBJECTIVE

The goal of this thesis is to describe the implementation of a gateway computer program, to demonstrate the utility and usefulness of such a system, and to evaluate its

effectiveness. This gateway program connects two major world-wide networks, the Internet and the Amateur Satellite Service.

D. THESIS ORGANIZATION

Chapter II is an overview of the Internet and the World Wide Web. The chapter also discusses the client and server programs used for accessing the World Wide Web and introduces the server program used on the *World Wide Web Amateur Satellite Ground Station* Gateway computer.

Chapter III is an overview of the Amateur Radio Service and the Amateur Satellite Service. This chapter also goes into detail on the Amateur Satellite ground station equipment and software used in the *World Wide Web Amateur Satellite Ground Station* Gateway.

Chapter IV explains the design and implementation of the *World Wide Web Amateur Satellite Ground Station* Gateway. It explains the operation of the Amateur digital communications satellites and the custom programs that creates the interface between the Amateur Satellite Service and the World Wide Web.

Chapter V discusses topics for further research for the *World Wide Web Amateur Satellite Ground Station* Gateway and draws some conclusions into the success of the project.

Appendix A is a list of manufacturers addresses and phones numbers for the equipment and software used in this project.

Appendix B is a summary of the usage logs kept during the five month operation of the *World Wide Web Amateur Satellite Ground Station* Gateway from April 11, 1995 to August 31, 1995.

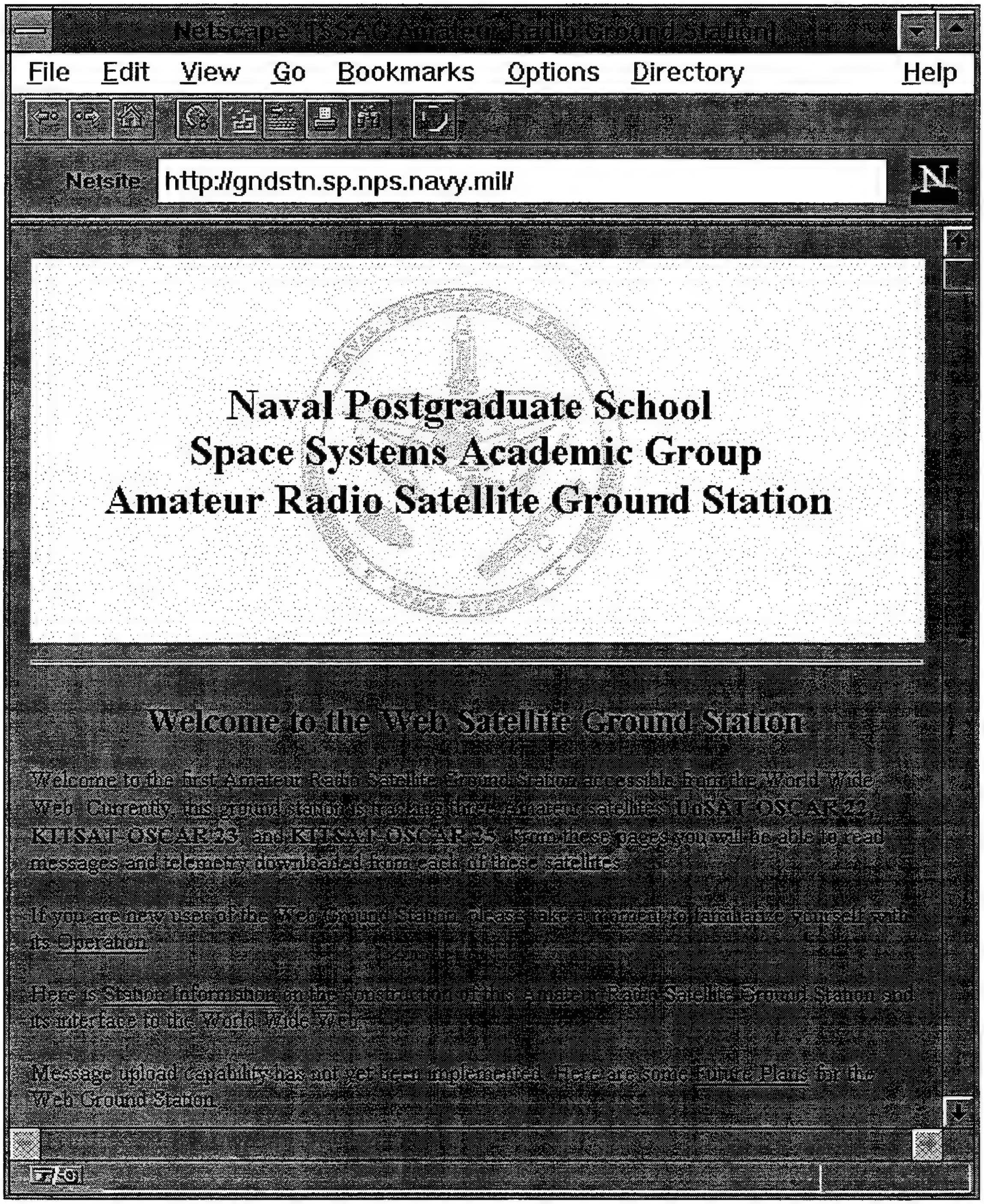


Figure 1. Home Page of the Web Ground Station

II. THE INTERNET AND THE WORLD WIDE WEB

In this chapter an overview of the Internet and the World Wide Web is presented. The World Wide Web, sometimes called the *Web* for short, is a fast growing segment of the Internet, integrating many of the services available on the Internet and providing unique services of its own. This chapter discusses the client and server programs used for accessing the World Wide Web and introduces the server program used on the *World Wide Web Amateur Satellite Ground Station* Gateway computer.

A. THE INTERNET

The Internet grew out of a number of projects initially funded by the United States government. Now, almost twenty-five years later, the Internet is a world-wide network of networks. A network is made up of connected computers each of which are called hosts. Local Area Networks (LAN) connect hosts within a building. Wide Area Networks (WANs) connect networks that cover college campuses or companies.

Computers on the Internet can communicate with other Internet computers, whether they are in the next room or on the other side of the world. To make communication between difference types of computers possible, the Internet uses a set of standards or protocols based on TCP/IP (Transmission Control Protocol/Internet Protocol) [3]. These protocols ensure that information stored on different types of computers can be transferred reliably across the Internet and provide a standard address format so that hosts know how to locate each other.

Local computers are called local hosts and other computers on a network are called remote hosts. The remote hosts on the Internet include PCs, workstations, and mainframe computers. A host that provides a service, such as access to a printer or files, is called a server. The hosts that take advantage of the service are called clients of the server. Other locations accessed on the Internet might provide still other services through specialized hosts and programs.

One challenge facing an Internet user is how to navigate over the network to access a world-wide network of documents, messages, pictures, video, services, and other forms of communication. The user needs to know how to find them and which program to use on them. The World Wide Web was created to interlink all of the different forms of information and integrate the programs necessary to retrieve them. Thus the World Wide Web has made navigating the Internet easier and more productive.

B. THE WORLD WIDE WEB

The World Wide Web [4] was conceived at the European Particle Physics Laboratory, CERN, in Geneva, Switzerland. The Web's designers sought to combine information from related projects through hypertext. Eventually, the University of Illinois' National Center for Supercomputer Applications (NCSA) took the idea one step further and created the popular NCSA Mosaic browser program. Since the introduction of the World Wide Web in 1990, its popularity has surpassed everyone's expectations. Prospective users can access the World Wide Web from work and school and through major information providers such as CompuServe® or America Online® as well as many local Internet Access Providers.

The World Wide Web is a collection of electronic documents, including text, pictures, sound and video. These documents provide a wealth of information on many different topics and are located on thousands of Web servers, also called Web sites, scattered across the Internet. A user accesses the World Wide Web using a browser program. When the browser program is started, the user begins at a home page. A home page is the main access point for a collection of documents. The home pages generally describe the organization providing information and what is available at the site.

The World Wide Web is based on the client-server model. The user "browses" or "navigates" the Internet or World Wide Web with a client program which requests files from server programs.

1. Client Software

A client program is used to explore the World Wide Web on the Internet. The program is frequently called a browser or navigator. It is aptly named because it describes how the user can explore the myriad of data sources available on the Internet. The browser program is a powerful, easy-to-use program designed to act as a universal access point for viewing and/or retrieving information over a network. It is an integrated program which incorporates many of the existing protocols used on the Internet. Thus the user can FTP files, search via gopher, and access Web pages using the native hypertext transfer protocol (HTTP), the protocol of the World Wide Web. Instead of having to figure out what to do with each file encountered, the navigator selects one of its helper applications to transfer and display it. Hypertext links various items such as text, images, movies or sounds. Thus the user does not need to know the location of the file of interest, instead selects the hypertext related to the file and the file is served.

Browsers are implemented using a text-based or graphical user interface (GUI). Text-based browsers indicate hypertext by intensified or bold text. The user makes their choice by tabbing to the desired hypertext and selecting it. GUI interfaces display hypertext by using an identifying color and/or underlining the text. The user selects the desired hypertext by pointing to it with a pointing device, such as a mouse, and clicking on the mouse button. The file is then served to the user.

Perhaps what has magnified the explosive growth of the World Wide Web is the ease of use of the graphically based browser programs. The look and feel of the browser is simple and intuitive to use. Command line prompts and memorizing of commands are not needed, instead selection is point and click. The first graphically based browser program was NCSA Mosaic, developed at the University of Illinois National Center for Supercomputer Applications (NCSA) [5].

In 1993 the University of Illinois' National Center for Supercomputer Applications (NCSA) developed NCSA Mosaic, a graphical browser program available for a variety of computing platforms. The availability of NCSA Mosaic for UNIX, MS Windows, and Macintosh extended the usability of the program. Users could select the appropriate program

for their platform. NCSA Mosaic became an instant success since it was available for free and users could FTP the client program from NCSA and be up and running instantly.

Once installed the user is able to access Web pages which are text files embedded with a simple markup language called hypertext markup language or HTML. HTML formats the text for presentation by the client program. Web page authors format the presentation by selecting the size and style of the fonts. HTML also provides linking of documents located on the local server or other servers on the Internet. Links can be to a variety of files: text, images, etc.

Since the introduction of NCSA Mosaic many other browser programs have been developed. Other universities and commercial ventures have entered the realm of developing and enhancing the capabilities of the World Wide Web through new innovations and standards. This commitment indicates the viability of the World Wide Web and the acceptance by the users of the Internet thus guaranteeing that the World Wide Web will continue to grow in the future.

2. Server Software

The World Wide Web client program requests files from a server program using hypertext transfer protocol (HTTP). Thus the name given to a Web server program is HTTPD or "hypertext transfer protocol daemon." There are several versions of HTTPD available for a variety of computing platforms. The version used for this project operates on Microsoft Windows and is called Windows HTTPD Version V1.4c, written by Robert Denny (see Appendix A).

When HTTPD is activated it waits for client requests. Requests are typically for HTML pages resident on the server machine. The pages are formatted by the author of the Web site, however, other files can be served as well, such as binary files, images, programs, or data. Therefore, the Web site can use a variety of media to enhance the display served to the client program.

The server program HTTPD has the ability to interface to "backend" programs. These are programs written to the interface programming specifications to link external programs with

the server [6]. This ability allows almost any command-line-driven external program to be interfaced to the Web server, thus allowing a user to access the external program. Data base programs are popular choices to interface to HTTPD. The user can form a query to the data base using the client program. The query is *p+9Xsent to HTTPD which passes the request to the external data base program via the backend program. When the result is formulated, it is passed to the backend program which formats the request in HTML and then passes it to HTTPD and finally to the requesting client program. This ability of writing backend programs greatly expands the usability of HTTPD. Now practically any application can be interfaced to the World Wide Web.

C. AMATEUR SATELLITE GATEWAY COMPUTER

The World Wide Web was a natural choice for this project. The World Wide Web server program HTTPD was integrated into an Amateur Satellite Ground Station to provide the gateway between the Internet and the Amateur Satellite Service. Implementation required two custom programs to be written to format information from the satellite ground station into the HTML language for the World Wide Web.

The World Wide Web was also chosen for its intuitive interface and flexible programming. The client program, or browser, is available for a variety of host computers and has become very popular with a large user audience. Therefore, training on the operation of the gateway was minimal since users were familiar with the use of the browser with other sites on the Internet. The pages for the project were easy to program using the HTML language. This demonstrated the flexibility and easily configurable nature of the project. As the project evolved and problems were encountered, they could be corrected quickly with little down time.

III. THE AMATEUR SATELLITE SERVICE

In this chapter an overview of the amateur radio service is presented first for those not familiar with its basis and purpose as outlined by the United States Federal Communications Commission (FCC). Next, an overview of the amateur satellite service is presented to give the reader an introduction to this expansive and worldwide system. Lastly, a detailed description of an Amateur Satellite ground station is presented complete with a description of the actual equipment and software used on the *World Wide Web Amateur Satellite Ground Station* Gateway.

A. BASIS AND PURPOSE OF THE AMATEUR RADIO SERVICE

Amateur Radio, sometimes called Ham Radio, is an international avocation of radio enthusiasts world-wide who build and operate radio stations for the purpose of communicating with one another. It is a service for the purpose of self-training, intercommunication and technical investigations carried out by Amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest [7]. In this definition, duly authorized means that an individual must be licensed by the respective regulatory organization.

In the United States the regulatory body governing the Amateur Radio service is the Federal Communications Commission (FCC). Upon passing an examination, the prospective Amateur is issued a license and call sign by the FCC. The call sign carries a special meaning to Amateurs. It becomes an alias for which they are known. In communications with other Amateurs, the rules and regulations require station identification every ten minutes and at the conclusion of the conversation. Thus the call sign serves the purpose of identifying that one is duly authorized and it also uniquely identifies the individual operating. The author of this thesis is a licensed Amateur Radio operator issued the call sign N7HPR.

The rules and regulations governing the Amateur Service is provided by Title 47 of the Code of Federal Regulations (CFR) Part 97. The rules are designed to promote the Amateur

Service in the United States to provide emergency communications, advance radio technology, improve operator skills, expand the numbers of trained operators, technicians, and electronics experts, and enhance international goodwill. Section 97.1 describes the basis and purpose of the amateur service, it consists of five principles:

> *1. Recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communication service, particularly with respect to providing emergency communications.*
>
> *2. Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.*
>
> *3. Encouragement and improvement of the amateur service through rules which provide for advancing skills in both the communication and technical phases of the art.*
>
> *4. Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.*
>
> *5. Continuation and extension of the amateur's unique ability to enhance international goodwill.*

Amateur Radio is an international service with each country's respective regulating body presiding over the rules and regulations that the service will abide by. Since the Amateur Radio Service is an international service, the frequency allocations are determined by the International Telecommunications Union (ITU). The ITU has the role of dividing the range of communications frequencies among all radio services. These services include commercial broadcast, land mobile, and private radio (including Amateur Radio). ITU member nations decide which radio services will be given certain bands of frequencies. The ITU makes these frequency allocations on an international basis. The Federal Communications Commission (FCC) makes frequency allocations in the United States for all civilian radio frequency communications including the Amateur Radio Service.

Twenty-seven bands of frequencies are allocated to the amateur radio service internationally. This brings the capability for licensed Amateur Radio operators to communicate with other licensed Amateurs in other countries. In addition to these frequency

bands, Amateurs can use different modes of communication that utilize analog, digital, pulse, and spread-spectrum techniques.

B. AMATEUR SATELLITE SERVICE

In keeping with the tradition of advancing the radio technique, amateurs soon began to explore space communications. This exploration began in 1961 when Project OSCAR built and launched OSCAR I [8]. OSCAR standing for Orbiting Satellite Carrying Amateur Radio, an acronym which has been attached to almost all Amateur Radio satellite designations on a world-wide basis [9]. To date there have been 45 amateur satellites launched into space with 16 still operational. Three launches did not reach orbit and one fell silent upon commissioning.

Amateur Radio operators world-wide communicate with each other via these satellites. Generally, there are two types of satellites: analog "bent pipe" and digital communications. Bent pipe satellites refer to spacecraft that carry an analog transponder which repeat the uplink transmission on a downlink frequency. These analog satellites operate as "repeaters in the sky," providing real-time voice communications. Digital satellites operate as a "bulletin boards in the sky," providing non-real-time message store-and-forward capabilities. An electronic message is uploaded to the satellite which in turn is downloaded by its intended receiver. The *World Wide Web Amateur Satellite Ground Station* tracks three digital communications satellites and provides a snap shot of the directory listings and messages downloaded from these satellites.

C. COMPONENTS OF AN AMATEUR SATELLITE GROUND STATION

1. Naval Postgraduate School Space Systems Academic Group (SSAG)

A Space Systems Academic Group (SSAG) Amateur Radio satellite ground station was constructed with the purpose of familiarizing NPS students on the operation of low-Earth orbit store-and-forward digital communications satellites. The ground station consists of various

hardware and software components. Figure 2 is a system block diagram of the *Web Ground Station*. A list of manufacturers names and addresses are given in Appendix A.

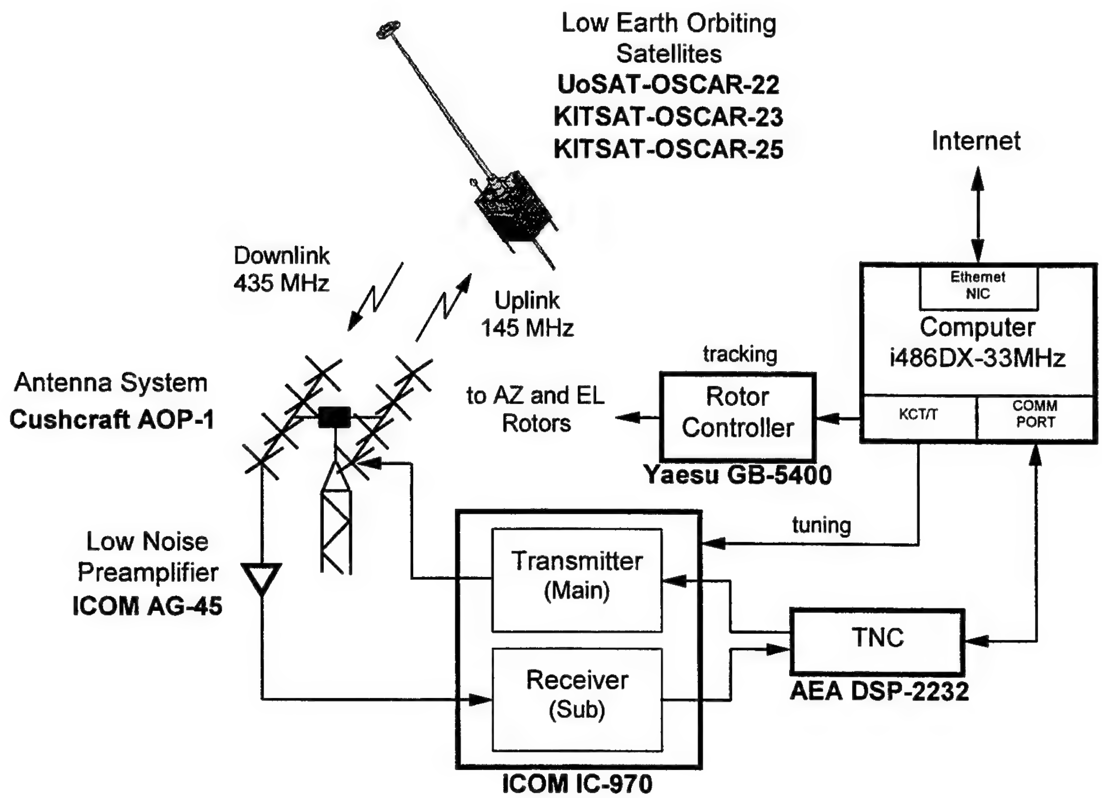


Figure 2. System Block Diagram of the Web Ground Station

2. Hardware

The hardware component of an amateur radio satellite ground station consists of three subsystems: radio, computer, and antenna. Figures 3 and 4 are photographs of the Amateur Satellite ground station components.

Figure 3. Radio and Computer Subsystems

The Radio System consists of a transceiver and radio modem. The transceiver is an ICOM Inc., model IC-970H multi-band all mode transceiver [10]. It is designed to handle two frequency bands: the 2 meter amateur band (144 - 148 MHz) and the 70 centimeter amateur band (430 - 450 MHz). The radio can be controlled manually from the front panel or by a computer.

The radio modem is an Advanced Electronics Applications, Inc., model DSP-2232 multi-mode data controller [11]. It interfaces between the computer and transceiver, changing the computer's binary data into Frequency Shift Keying (FSK) modulation for the radio, and vice versa. The modem employs digital signal processing techniques that make this modem both flexible to use and easy to upgrade.

The computer subsystem has a 486DX-33 MHz computer with 8 Megabytes of RAM and a 240 Megabyte hard drive. A L. L. Grace "Kansas City Tracker/Tuner" (KCT/T) [12] card is plugged into an expansion slot. The KCT/T provides the interface between the computer and the antenna rotor controller (for tracking) and transceiver (for tuning). An Ethernet Network Interface Card (NIC) is plugged into another expansion slot and provides the ground station's interface to the campus network and Internet.

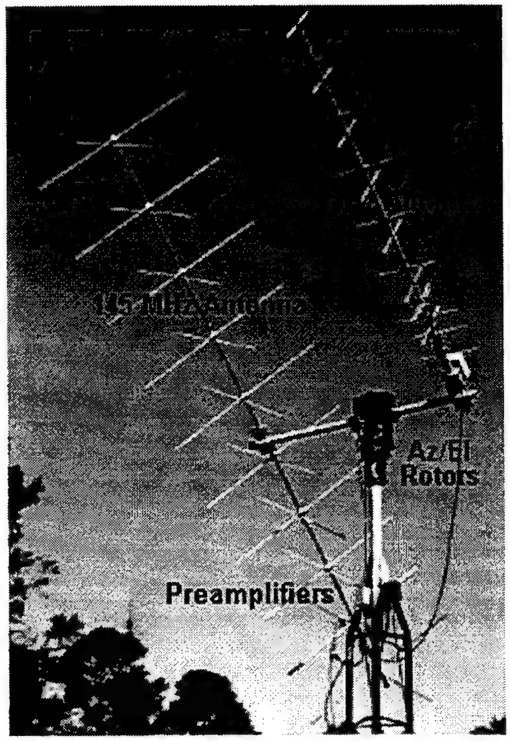


Figure 4. Antenna Subsystem

The Antenna System consists of two antennas (up-link and down-link), two rotors (azimuth and elevation), and down-link preamplifier. The antennas are manufactured by Cushcraft Corp., model number AOP-1 [13], and are of the crossed yagi design. A yagi antenna has multiple elements mounted on a boom. The elements are divided up into one relector, one driver, and several director elements all mounted in the same plane. A crossed yagi antenna has two planes of elements mounted on the same boom 90 degrees opposed. They are electrically fed 1/4 wavelength apart. This allows the antennas to transmit and receive circular polarized signals from the satellites as they spin in space for stabilization. The Cushcraft AOP-1 consists of an A144-20T 146 MHz antenna, a 416-TB 435 MHz antenna, and a A14T-MB support cross boom with mounting plate.

The azimuth/elevation rotors are manufactured by Yaesu Co. Ltd., model number G-5400B [14]. This system has an integral pair of rotors: one controlling the antenna's azimuth (0-360 degrees) and the other controlling elevation (0-90) degrees. The Kansas City

Tracker/Tuner interface card interfaces with the rotor controller and allows for computer control of the antenna system.

The preamplifier is manufactured by ICOM, Inc., model number AG-35 [15]. It is located on the mast below the antennas and amplifies the weak signal received from the satellites before sending it to the transceiver.

3. Software

The software component of an amateur radio satellite ground station consists operating system, Windows Satellite Program, and Windows httpd web server programs.

The operating system is Microsoft® Windows™ for Workgroups Version 3.11 with 32-bit extensions (Win32s) and TCP/IP protocol stack (Wolverine).

Windows Satellite Program (WiSP) controls both satellite tracking and message upload/download functions. WiSP is written by Chris Jackson, G7UPN/ZL2TPO, of Surrey Satellite Technology Limited of the University of Surrey. WiSP is an integrated suite of seven programs that schedules, tracks, tunes, composes and views messages, and transfers files to and from the satellites. Below is a short description of each of the software modules.

Ground Station Control (GSC) - This program provides housekeeping and scheduling functions for the complete ground station package. Features include file deletion and log processing along with system wide setup functions. GSC is the central program. It schedules satellite passes and calls upon subordinate programs for individual tasks. For example, when a satellite comes into view, GSC calls up MicroSat Protocol Engine (MSPE) to decode the down-link from the satellite. When a complete message has been captured, MSPE calls upon Process Mail to remove the message header information and store the message in the appropriate directory. When the pass is complete, GSC terminates MSPE and waits for the next satellite pass.

MicroSat Protocol Engine (MSPE) - This program provides all the uploading and downloading functions required to access the satellites.

View Directory (View-Dir) - This provides the directory viewing and message viewing/reply functions, along with some message housekeeping functions.

Message Maker (MsgMaker) - All message creation and replies are performed through Message Maker. It gives the user a large amount of flexibility when sending messages and binary files while still providing a quick, automated function.

Process Mail (ProcMail) - Processes received messages as they are downloaded from the satellite, and places them in the required directories for viewing.

Message Viewer (MsgView) - Views all ASCII messages received from the satellite. Messages can be replied to and deleted.

Update Keps (UpdKeps) - Automatically updates the keplerian database when new keps files are received from the satellite.

WiSP Telemetry (WiSP-TLM) - The WiSP Telemetry decoder works with MSPE to display real time telemetry while the pass is in progress or display telemetry from a file.

The KCT/T Windows driver program was written by David Hoatson, KC6WYG, a professional programmer and Amateur Satellite enthusiast. It interfaces WiSP with the KCT/T card. The driver is configured for the ICOM IC-970 transceiver and Yaesu G-5400B rotors. The KCT/T interface card provides the interface between computer and the transceiver (for tuning) and antenna rotor controller (for tracking).

The World Wide Web server program is Windows httpd V1.4c written by Robert B. Denny, 221 South Oak Knoll Avenue, Suite 207, Pasadena, CA 91101. The program runs under Windows 3.1 or Windows for Workgroups 3.11 and serves requests by the World Wide Web client program for pages on the *World Wide Web Amateur Satellite Ground Station*.

IV. GATEWAY DESIGN AND IMPLEMENTATION

This chapter explains the design and implementation of the *World Wide Web Amateur Satellite Ground Station* Gateway. The gateway interfaces the Amateur Satellite Service and the Internet so that users can access the message database of each satellite via the World Wide Web. First, the operation of Amateur digital communication satellites known as PACSATs (packet satellites) is presented to familiarize the reader on message exchange between the satellites and ground station. Next, a discussion on the design and implementation of two custom programs, PFH2HTML and TLM is outlined. Finally, a discussion on the integration of these custom programs with a World Wide Web server and how it creates the gateway between the Amateur Satellite Service and the World Wide Web.

A. PACKET SATELLITES (PACSAT)

The Amateur Satellite ground station tracks and exchanges files with three Amateur low-Earth orbit, digital communications, store-and-forward satellites: UoSAT-OSCAR-22, KITSAT-OSCAR-23, and KITSAT-OSCAR-25 [16]. These satellites communicate via 9600 bps FSK full duplex up and down-links using the PACSAT Protocol Suite [17].

1. Message Exchange

Messages uploaded to the satellites are prepared by the ground station software. The body of the message can be either text or binary information. The body is appended to a header which contains such information as the call sign of the originating and receiving stations, title of the message, date and time of upload, and keywords. There are 28 possible fields in the header, divided into mandatory, extended, and optional categories [18] (Figure 5). When messages are uploaded to the satellite, the header information is removed and stored in the satellite's directory. The body of the message is assigned a sequential hexadecimal file number and stored in the satellite's memory.

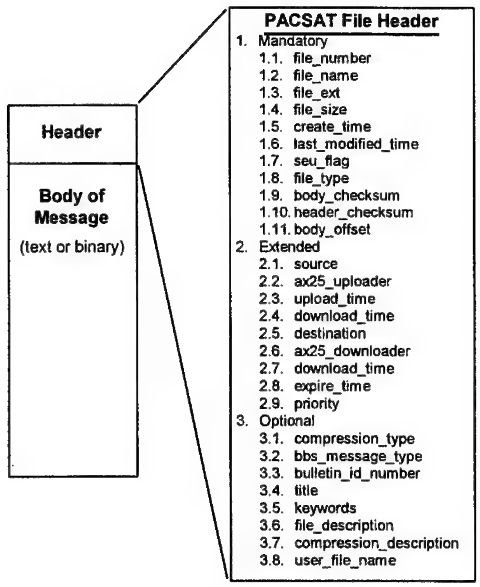


Figure 5. PACSAT messages are made up of the header and the body

Each satellite transmits their directory listing separately from messages and files. This method facilitates a large number of ground based users each contending for resources on the satellite. Ground stations receive directory information from the satellite and scan it for messages that meet download criteria. If any messages are addressed to the call sign of the station or to ALL, the ground station signals the satellite to transmit the message.

Since the directory is transmitted separately from messages and files, the ground station computer maintains a listing of all the messages that reside on the satellite. When a message is transmitted to the ground station, only the body of the message is sent and the identity of the message is only known by its hexadecimal file number. Therefore, the ground station computer only maintains those messages addressed to it, to ALL, or messages overheard when broadcast to another ground station within the footprint of the satellite. When using the WiSP Message View program to read messages, the directory files are used to associate header information with the body of the message.

2. Ground Station Computer

When directory listings, messages, or telemetry are downloaded, WiSP places them in their respective directories on the ground station computer (Figure 6). Directory listings have the filename MSPExxxx.PFH. The prefix MSPE stands for the MicroSat Protocol Engine, the program responsible for decoding information to and from the satellites. The xxxx is a sequential number assigned by WiSP. The PFH extension identifies the file as written in the PACSAT File Header (PFH) format. WiSP stores messages downloaded from the satellites in their original form: text for messages and binary for files. Text messages are stored in the MSGS subdirectory with the hexadecimal file number and MSG extension. Binary files are stored in the BIN subdirectory. Telemetry is captured by WiSP and labeled with a time stamp in the form of YYMMDDHH and an extension of TLM. Figure 7 summarizes the information flow from the satellite to the ground station computer.

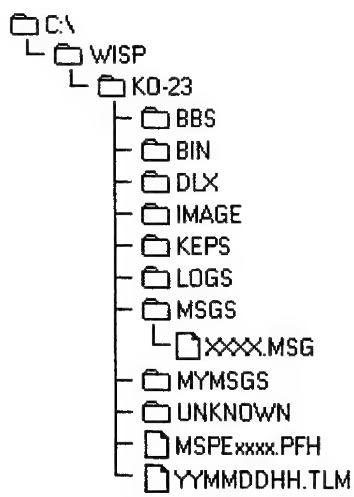


Figure 6. Directory Structure of WiSP (only KO-23 shown)

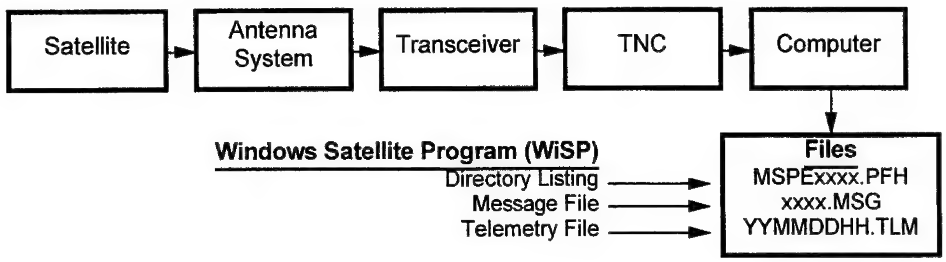


Figure 7. Information flow from the satellite to the ground station computer

3. Flow of Information

In summary, the ground station has the responsibility of tracking three satellites and placing directory, message, and telemetry files in the appropriate directories on the hard drive of the ground station computer. Next, the custom programs PFH2HTML and TLM convert the directory listings and raw telemetry files, respectively, to their HTML counterparts. These custom programs are schedule by WiSP to run two minutes after each satellite pass. It is then the responsibility of the World Wide Web server program to serve these HTML files to the users who request them. Figure 8 summarizes the flow of information between the files which WiSP writes to the ground station computer and the custom programs that format them into their HTML counterparts for the *Web* server.

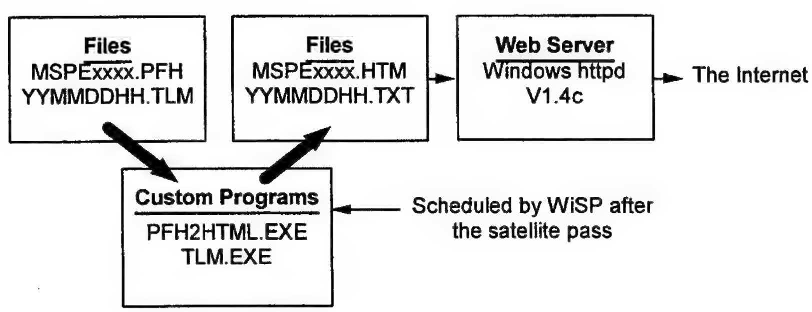


Figure 8. World Wide Web Server Information Flow

B. CUSTOM PROGRAMS

1. PFH2HTML

The first custom program written is called PFH2HTML.EXE. Its purpose is to read the MSPExxxx.PFH file, parse it according to the PFH protocol [13], and write a text file directory listing in HTML format for the web server. PFH2HTML is a MS-DOS program written in the C language. It was written by modifying the source code from **directory**, a directory list viewer from MicroSat Ground Station Software [19] written by John Melton, G0ORX/N6LYT, for the Linux operating system [20]. Licensing and copyright of the program is under the GNU Public License [21]. It is freely redistributable with no warranty.

Modification of **directory** required stripping the program of the X-Windows source code and adding source code to format the output in HTML format. This modification, also called "code reuse," allowed for the rapid coding of the program PFH2HTML thus reducing the time needed to program it from scratch.

Operation of PFH2HTML begins by reading the MSPExxxx.PFH file. Since MSPExxxx.PFH is a binary file, it must be parsed according to the PFH protocol. Each entry in MSPExxxx.PFH is a header to a message body that resides on the satellite. Some of these messages also reside on the ground station computer. As PFH2HTML parses each entry in the file, it checks in the message directory C:\WISP\KO-23\MSGS\ (using KO-23 as an example) on the ground station computer to determine if the message is resident. If it is, then PFH2HTML creates a hyperlink to the associated message. If not, then ordinary text is written. The resulting output is a text file formatted in the HTML language for the web server. Figure 9 shows the HTML formatted directory listing for KO-23 from a web client program.

The resulting HTML formatted directory listing has four columns: Title, To, From and Upload Date and Time. If a message is resident on the ground station computer, the title of the message is underlined indicating a hyperlink to the associated message. The user selects the hyperlink and the web server sends the message to the client program. Hyperlinks allow the user to see at a glance which messages are available to read. This is an elegant interface and

an excellent demonstration of the power of hyperlinks. The interface is intuitive, easy to use, and does not distract the user.

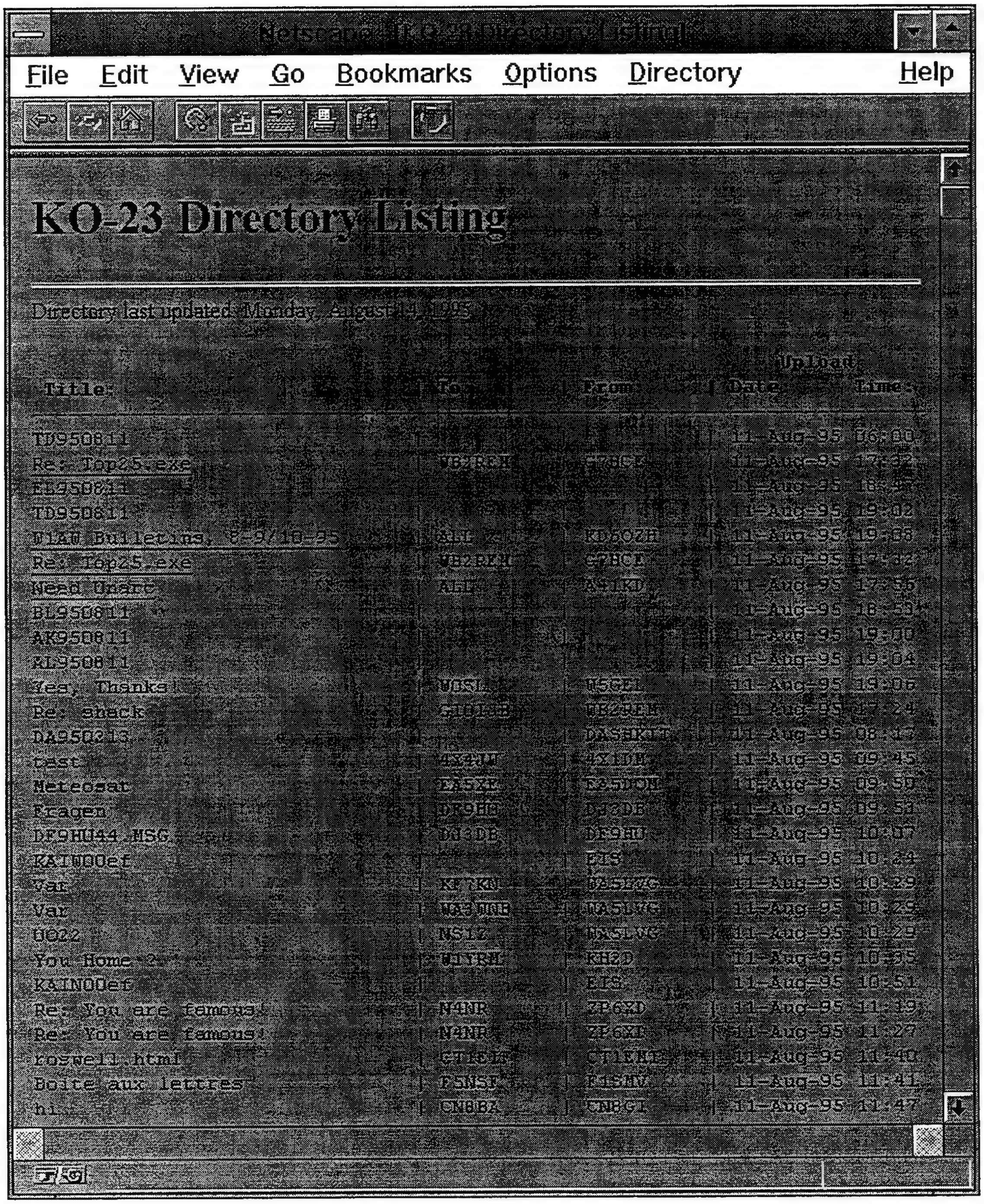


Figure 9. KO-23 directory listing

2. TLM

The second custom program, called TLM.EXE, reads the raw telemetry file, decodes it, and writes a text file. The decoding format for the telemetry is given in reference [22]. TLM is a MS-DOS program written in the C language. It was written by modifying the source code from **xtlm**, a telemetry viewer from MicroSat Ground Station Software written by John Melton, G0ORX/N6LYT, for the Linux operating system. Licensing and copyright of the program is under the GNU Public License. It is freely redistributable with no warranty.

Modification of **xtlm** required stripping the program of the X-Windows source code and adding source code to format the output in text format. This modification, also called "code reuse," allowed for the rapid coding of the program TLM thus reducing the time needed to program it from scratch.

Operation of TLM begins by reading the latest YYMMDDHH.TLM file in the directory C:\WISP\KO-23\ (using KO-23 as an example). Since YYMMDDHH.TLM is a binary file, it must be parsed according to the telemetry format. The resulting output is a text file which is a snapshot of the decoded telemetry. Both the raw telemetry file and the decoded text file are available for the user to select from. Users can choose to read the decoded telemetry or download the raw telemetry for later decoding with their own program.

C. THE WEB SERVER AND THE USER INTERFACE

The final software component of the *World Wide Web Amateur Satellite Ground Station* Gateway is the World Wide Web server program HTTPD. HTTPD runs on the ground station computer in parallel with WiSP. The custom programs PFH2HTML and TLM are scheduled by WiSP to run two minutes after the satellite pass for each satellite. Once the HTML formatted directory listing and decoded telemetry are written by the custom programs, they are immediately available to the web server. Thus the user has access to the message database and telemetry from each satellite in near real-time.

The web server is the interface to the Amateur Satellite ground station. The web server allows the user to interact with the ground station by selecting web pages that describe the operation and construction of the gateway and provide links to the message database and telemetry of the satellites. Programming of the user interface consists of designing a series of text web pages formatted in the HTML language. Therefore, the design of the user interface must:

- be programmed using the HTML language,
- follow good user interface design criteria,
- be easy to use, and
- not be distracting.

The user interface is an important component of the Web Ground Station. Without an intuitive and easy to use interface, the ability of a prospective user to successfully navigate the mired of pages would be hampered, thus leaving the user confused and ineffective in operating the ground station. If properly designed, prospective users of the gateway will learn how to use the gateway in minimum time and, hopefully, find the operation of the gateway enjoyable and easy to use. The World Wide Web with its hypertext user interface can easily meet these objectives.

1. Hypertext

Hypertext consists of interlinked pieces of text (or other information) [23]. On the World Wide Web browser, hypertext can be indicated in a number of ways. For a text based browser, the hypertext is emphasized by bolding or intensifying. In a graphically based browser, the hypertext is indicated by a change of the color and/or underlining the text. By making text stand out in this fashion, the user knows that further information is "linked" to it. Selection of this linked information is as simple as selecting the text and pressing ENTER or clicking on the mouse button.

Hypertext is nonsequential. Unlike reading a book, which is sequential reading, hypertext allows users to choose which direction they want to go. Designing the user interface using this nonsequential method requires a different design approach than, say, writing a book. For example, a user interface can employ menus, a favorite among text based user interfaces. The menus are constructed to give the user a choice of commands. When a choice is made, another menu is presented to the user, indicating the next range of choices. Hypertext takes on a similar, and familiar, structure. The difference is that hypertext can be embedded in a paragraph or a picture. The designer is not limited to a linear set of choices. The *World Wide Web Amateur Satellite Ground Station* Gateway exploits hypertext's nonsequential and embedded-links-within-paragraphs method.

2. Gateway Web Page Design

The first page, called the "home page," is the top most page that welcomes the novice or expert user to the *World Wide Web Amateur Satellite Ground Station* Gateway (Figure 1). The user gets to the home page by entering the Uniform Resource Locator (URL) into the web browser program. The URL of the *World Wide Web Amateur Satellite Ground Station* Gateway is:

http://gndstn.sp.nps.navy.mil

The home page is formatted with a distinctive graphic and welcoming message. The graphic provides a unique visual identification of the ground station. The welcoming message greets the prospective user and informs them of the purpose of the gateway. For the first time user of the gateway, they are greeted with the following statement:

> If you are a new user of the Web Ground Station, please take a moment to familiarize yourself with its **Operation**.

Here, the word "operation" is a hyperlink to another web page that explains the operation to the novice user. If expert users revisit the home page, they can skip the link and scroll down the home page to select a desired link. For the inquisitive, the statement:

> Here is **Station Information** on the construction of this Amateur Radio Satellite Ground Station and its interface to the World Wide Web.

This is an invitation to learn more about the station construction and implementation. This is the "virtual classroom" of the Web Ground Station. Not only can the primary mission of the gateway be used to access the message database of the satellites it tracks, but it can inform, teach, and enhance the knowledge needed to understand and use the ground station.

The links among pages form a circular tree data structure. Pages can link to multiple pages. Links can also return the user to the previous page. Links are constructed by the author, therefore, the author needs to carefully plan the contents of each page and anticipate the users moves. Both novice and expert users need to be kept in mind.

Figures 10 and 11 illustrate the major links between the web pages on the *World Wide Web Amateur Satellite Ground Station* Gateway. From the home page the user can select one of four paths: station operation, station information, future plans, and satellite selection. Each of these paths lead the user to more information related to the subject selected. Return links are provided for each of the pages to allow the user to return to the top of the subject. This keeps the user informed that the end of the topic has been reached. Sometimes links lead to other subjects. This is to provide the user with a choice of moving on to the next topic without having to traverse to the top most page. This design decision was made in anticipation of what the user may do when reading the pages for the first time. It is also anticipated that an expert user will go directly to the satellite selection, bypassing all the introductory material.

3. Summary of each Web Page

Each web page on the *World Wide Web Amateur Satellite Ground Station* Gateway serve a specific purpose. The following is a brief summary of each.

Station Operation -- Introduction into the operation of the gateway. Intended for first time or infrequent users.

Station Information -- A "jump off" page allowing the user to select from one of three pages that explain in more detail the hardware, software, and World Wide Web interface of the gateway.

Future -- An information page telling the inquisitive user of the expected enhancements being programmed into the gateway.

Hardware Description -- Describes each of the hardware components of the Amateur Satellite ground station. Contains photographs of the equipment.

Software Description -- Describes the software employed on the Amateur Satellite ground station. Contains images of the program windows.

Web Interface -- Explains how the Amateur Satellite ground station is interfaced to the World Wide Web.

ICOM -- Description of the transceiver.

AEA -- Description of the data controller.

KCT/T -- Description of the tracker/tuner interface card.

Cushcraft -- Description of the satellite antenna system.

Yaesu -- Description of the azimuth/elevation rotor system.

ICOM2 -- Description of the preamplifier.

UO-22, KO-23, and KO-25 -- "Jump off" pages for each respective satellite that the ground station tracks. These pages allow the user to select to view messages, images or telemetry downloaded from the satellites.

Directories -- From the directories, the user can select messages to read.

Images -- Images downloaded from the satellites which were uploaded by Amateurs around the world.

Telemetry -- Raw and decoded telemetry from the respective satellite.

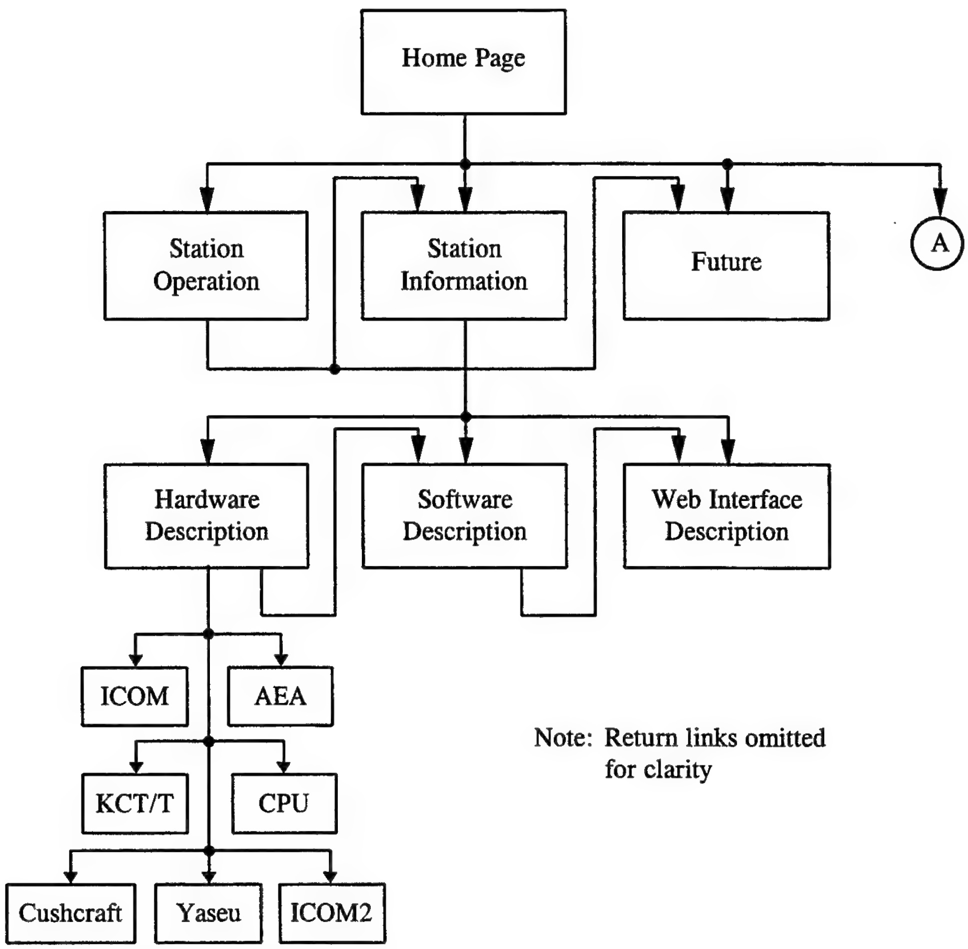
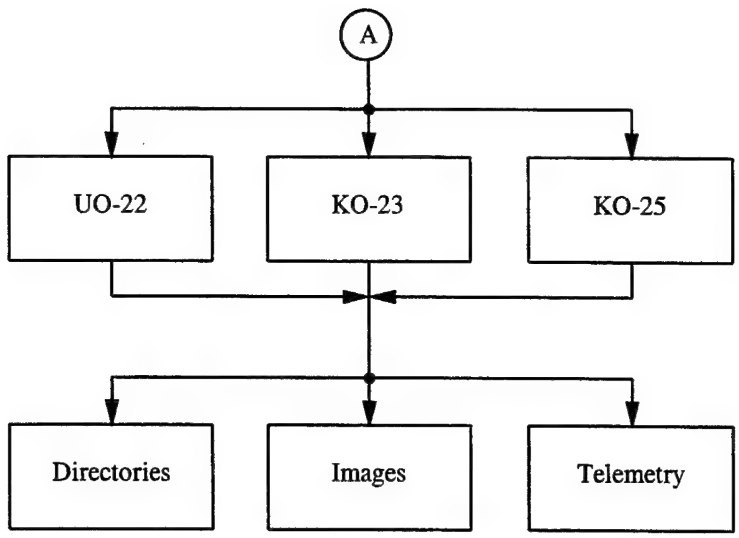


Figure 10. Hyperlinks to Information Web Pages



Note: Return links omitted
for clarity

Figure 11. Hyperlinks to Satellite Web Pages

V. TOPICS FOR FURTHER RESEARCH AND CONCLUSIONS

A. TOPICS FOR FURTHER RESEARCH

The Web Ground Station started out as a project in connecting two dissimilar networks and demonstrating the utility and usefulness of such a system. Never before have these two networks been connected. Therefore, there was no previous data that could be analyzed to determine if such a gateway would be useful and have a bonafide purpose. After several months of operation it became clear that the gateway indeed has these qualities. Below are ideas that came from discussions with two professors in space programs at Stanford University (SU), California and the University of Alabama, Huntsville, (UAH).

Education -- The World Wide Web Amateur Satellite Ground Station Gateway can educate people in the operation of digital communications satellites. It can also inform people in the construction of a satellite ground station. The present web pages do both of these functions.

Dissemination of Information -- There are several university space programs in the United States, there is one at Stanford University, California and another at the University of Alabama, Huntsville. Both are interested in the potential of a gateway station in accessing and disseminating information from their respective spacecrafts. Each being a research project, the ability to access the experimental data is attractive. Both universities are considering using the gateway concept and the World Wide Web to perform these functions.

Message Passing -- Presently, messages on the Web Ground Station are read only. There is no message upload capability programmed into the World Wide Web interface. To implement this is not difficult. It was not performed due to the lack of time. Since the Web Ground Station is implemented using Amateur Satellites, there is a large user base from which to draw. This provides the opportunity to test the interface and robustness of the implementation. However, since messages are being sent via Amateur frequencies, the FCC rules and regulations pertaining to the Amateur Radio Service must be followed.

Selective Uploading of Messages -- It is desirable that a message be delivered from Point A to Point B in the shortest amount of time. When uploading a message to a low-Earth orbit store-and-forward satellite, the amount of time for a message to travel from Point A to Point B is a function of the satellite's orbit. Generally, these satellites will pass over the same location 6 to 7 times per day. The worst case scenario for passing a message can be on the order of 5 to 6 hours. To improve this situation, several satellites can be used, however, some method of knowing which satellite to upload the message is needed.

The Web Ground Station gateway upload capability can be enhanced by implementing an algorithm to choose one of the three satellites a message will be uploaded in order to minimize the length of delivery time. The algorithm would be aware of the satellites in orbit, their orbital parameters, and times of arrival at the gateway and message destination. Thus the user only has to submit the message to the gateway and allow it to choose which satellite the message will be uploaded to. This frees the user from determining which satellite will carry the message to its destination and delivery time is minimized.

Security -- Network security is a major concern on the Internet. For the *World Wide Web Amateur Satellite Ground Station* to be a viable gateway, network security must be implemented. Since the gateway in its present state is read-only, the security measures are minimal. However, when upload capabilities are implemented, authentication of the users is necessary.

The system administrator of the gateway must have a method of authenticating the users who plan to upload messages to a satellite. Therefore, one option is to issue a password to each user. Implementing a password system to the web server is easy to perform since it is an intrinsic function of the web server program. A second option that is in development for the World Wide Web is secure http. Using this method, a message can be encrypted thus guaranteeing that the message cannot be altered or spoofed. It also adds another form of authentication by employing encryption keys to the user. This adds another layer of security to the gateway and ensures the integrity and viability of messages being passed.

Operating System Upgrade -- The Web Ground Station was originally implemented using Microsoft Windows for Workgroups (WfW) Version 3.11. Throughout the test period it was determined that WfW could not handle high volumes of accesses to the World Wide Web

server. Therefore it would be best to use a more robust operating system. Since WiSP is written for Microsoft Windows, the choice of operating systems is small. The author of WiSP is (as of this writing) actively porting WiSP to Microsoft's 32-bit operating systems Windows 95 and Windows NT. Thus the best option would be to implement the gateway on a Windows NT platform.

A second possibility would be to implement the gateway using the Linux operating system. John Melton's MicroSat Ground Station Software could be modified to the same functionality as WiSP. This would create an excellent platform for the gateway and can take advantage of the many attributes of the UNIX operating system.

B. CONCLUSIONS

The *World Wide Web Amateur Satellite Ground Station* Gateway was placed into general use on April 11, 1995. Announcement was made to an Internet list server that reaches a world wide audience of Amateur Satellite enthusiasts. On April 12, 1995, 991 accesses were logged. Accesses of the gateway continued at the average of approximately 350 per day from the introductory date to 31 August 1995 from 41 countries and 3057 host computers. Accesses for the month of August alone averaged 550 per day. A summary of the access logs are given in Appendix B.

During the five month period, over 60 email messages were received from Amateur Satellite enthusiasts commenting on the uniqueness, utility, and originality of the Web Ground Station. Here are a representative sample received during the early phases of the gateway operation.

> What an incredible effort you have made with this. You have given the non-space type hams a really good look at what it is like on the digital birds. -- Mark Hammond, KC4EBR

> This is a fantastic display of current technology! Well done! You just became my favorite "cool stuff" to show my users the capability of the Web and Ham radio. Everyone will want to see this. -- John Schweiger, N8YAU

> GREAT JOB! It seems real good to show new guys what its all about. Your spectacular full color introduction is likely to get more people interested

and I think their next logical question is what birds and frequencies? Congratulations again and keep up the great work. -- Kevin Bierney, N6CWF

What a great way to get the satellites into our classrooms!! We will use it a lot. Good luck on the installation. -- Dave Reeves, KF6PJ/WA6BYE

You have really done something new, what never have been done before. Many hams (or even non-radio amateurs) will be able to see what radio amateurs and amateur radio satellites can do or a capable to do...congratulations to your brilliant idea and you can be sure, that I will look into your Web Satellite Ground Station from time to time. -- Peter Guelzow, DB2OS

B R I L L I A N T !!! - James Miller, G3RUH

Several papers have also been published on the Web Ground Station [23 - 27].

The gateway was a resounding success witnessed by the enthusiastic acceptance by the Amateur Satellite community. Judging by the number of accesses per day and the world-wide use of the gateway, operation of the gateway has gained a large following. It has gained the interest of the academic community both in secondary schools and universities. The operation of the gateway during the five month period has allowed many people around the world the ability to investigate possibilities for an Internet to satellite gateway that were previously unexplored. It has also invoked a dialog into many possible enhancements and uses for the gateway in real world situations.

The *World Wide Web Amateur Satellite Ground Station* Gateway continues to operate from the Space Systems Academic Group laboratories at the Naval Postgraduate School in Monterey, California. It has been adopted as a research project within the Satellite Development Group.

APPENDIX A. LIST OF MANUFACTURERS

A. HARDWARE

1. 486DX-33 MHz PC-AT

IBM PC-AT Clone with 8 Megabytes RAM, 270 Megabyte hard drive, and 17 inch color monitor. Available from various manufactures.

2. Kansas City Tracker and Tuner

Manufactured by L. L. Grace Communications Products, P.O. Box 1345, Voorhees, NJ 08043. Telephone: (609) 751-1018. Fax: (609) 751-9705.

3. ICOM, Inc. IC-970H V/UHF Multi-band All Mode Transceiver

Manufactured by ICOM Inc., Corporate Headquarters, 2380-116th Ave. N.E., Bellevue, WA 98004. Telephone: (206) 450-6088.

4. Advanced Electronics Applications, Inc., DSP-2232 Data Controller

Manufactured by Advanced Electronic Applications, Inc., 2006 196th St. S.W., P.O. Box C2160, Lynnwood, WA 98036. Telephone: (206) 774-5554.

5. Cushcraft Corp., AOP-1 Amateur Satellite Antennas

Manufactured by Cushcraft Corp., 48 Perimeter Road, P.O. Box 4680, Manchester, NH 03108. Telephone: (603) 627-7877. Fax: (603) 627-1764.

6. Yaesu G-5400B Antenna Azimuth-Elevation Rotator and Controller

Manufactured by Yaesu Musen Co., Ltd., 17210 Edwards Road, Cerritos, CA 90701. Telephone: (310) 404-2700.

7. ICOM Inc., AG-35 Preamplifier

Manufactured by ICOM Inc., Corporate Headquarters, 2380-116th Ave. N.E., Bellevue, WA 98004. Telephone: (206) 450-6088.

B. SOFTWARE

1. Windows Satellite Program (WiSP)

Available from AMSAT-NA, 850 Sligo Avenue, Sliver Spring, MD 20910-4703. Telephone: (301) 589-6062.

2. Windows httpd V1.4c

Available from Robert B. Denny, 221 South Oak Knoll Avenue, Suite 207, Pasadena, CA 91101. Also available from http://www.city.net/win-httpd/.

3. Win32s (32-bit extensions) and Wolverine (MS TCP/IP)

Available from http://www.microsoft.com

APPENDIX B. USAGE STATISTICS

The following statistics were compiled from the access logs generated by HTTPD using a program named wwwstats. The statistics have been normalized by removing the access requests for images within the web pages. For example, the home page has seven embedded images. For every one user access of the home page, the server logs eight accesses -- one for the text and seven for the images. Also, some days are missing from the statistics. These are days the that the gateway was not operational either due to maintenance or system lockup.

A. DAILY TRANSMISSION STATISTICS

Requests	Date
166	Apr 11 1995
991	Apr 12 1995
380	Apr 13 1995
278	Apr 14 1995
80	Apr 15 1995
25	Apr 16 1995
24	Apr 17 1995
65	Apr 18 1995
933	Apr 19 1995
200	Apr 20 1995
111	Apr 21 1995
302	Apr 22 1995
87	Apr 23 1995
212	Apr 24 1995
188	Apr 25 1995
192	Apr 26 1995
224	Apr 27 1995
275	Apr 28 1995
95	Apr 29 1995
89	Apr 30 1995

Requests	Date
160	May 1 1995
98	May 2 1995
204	May 3 1995
287	May 4 1995
136	May 5 1995
70	May 6 1995
92	May 7 1995
200	May 8 1995
369	May 9 1995
214	May 10 1995
221	May 11 1995
297	May 12 1995
224	May 13 1995
130	May 14 1995
221	May 15 1995
484	May 16 1995
141	May 17 1995
109	May 18 1995
118	May 26 1995
117	May 27 1995
153	May 28 1995
184	May 29 1995
313	May 30 1995
191	May 31 1995
271	Jun 1 1995
161	Jun 2 1995
24	Jun 4 1995
256	Jun 5 1995
181	Jun 6 1995
147	Jun 7 1995
269	Jun 8 1995
299	Jun 9 1995
131	Jun 10 1995
115	Jun 11 1995
203	Jun 12 1995

Requests	Date
248	Jun 13 1995
239	Jun 14 1995
59	Jun 15 1995
121	Jun 19 1995
164	Jun 20 1995
133	Jun 21 1995
28	Jun 22 1995
85	Jun 23 1995
182	Jun 24 1995
107	Jun 25 1995
100	Jul 2 1995
192	Jul 3 1995
281	Jul 4 1995
323	Jul 5 1995
54	Jul 10 1995
469	Jul 11 1995
966	Jul 12 1995
782	Jul 13 1995
976	Jul 14 1995
576	Jul 15 1995
610	Jul 16 1995
377	Jul 17 1995
507	Jul 18 1995
439	Jul 19 1995
396	Jul 20 1995
315	Jul 21 1995
303	Jul 23 1995
273	Jul 24 1995
509	Jul 25 1995
480	Jul 26 1995
469	Jul 27 1995
231	Jul 28 1995
38	Jul 29 1995
384	Jul 30 1995
724	Jul 31 1995

Requests	Date
444	Aug 6 1995
921	Aug 7 1995
1414	Aug 8 1995
453	Aug 9 1995
893	Aug 10 1995
812	Aug 11 1995
138	Aug 12 1995
613	Aug 14 1995
561	Aug 15 1995
575	Aug 16 1995
423	Aug 17 1995
356	Aug 18 1995
307	Aug 19 1995
232	Aug 20 1995
649	Aug 21 1995
719	Aug 22 1995
471	Aug 23 1995
276	Aug 24 1995
360	Aug 25 1995
482	Aug 26 1995
370	Aug 27 1995
528	Aug 28 1995
391	Aug 29 1995
377	Aug 30 1995
470	Aug 31 1995

B. TOTAL TRANSFERS BY CLIENT DOMAIN

Requests	Domain	
30	at	Austria
636	au	Australia
38	be	Belgium
50	br	Brazil
912	ca	Canada
210	ch	Switzerland
10	cl	Chile
1	cz	Czech Republic
415	de	Germany
20	dk	Denmark
1	do	Dominican Republic
3	ec	Ecuador
1	eg	Egypt
393	es	Spain
298	fi	Finland
90	fr	France
1	gb	Great Britain (UK)
32	gr	Greece
7	hk	Hong Kong
14	hu	Hungary
70	id	Indonesia
37	ie	Ireland
150	il	Israel
2	is	Iceland
199	it	Italy
700	jp	Japan
25	kr	Korea (South)
115	mx	Mexico
524	my	Malaysia
139	nl	Netherlands
111	no	Norway
140	nz	New Zealand (Aotearoa)
11	pl	Poland

Requests	Domain	
102	pt	Portugal
10	ru	Russian Federation
260	se	Sweden
1	sg	Singapore
2	su	USSR (former)
63	th	Thailand
12	tw	Taiwan
781	uk	United Kingdom
518	us	United States
66	za	South Africa
14020	com	US Commercial
3570	edu	US Educational
373	gov	US Government
1926	mil	US Military
3909	net	Network
792	org	Non-Profit Organization
3	arpa	Old style Arpanet
6235	unresolved	

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